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ANALYSIS OF THE ENERGY COST OF ECONOMIC ACTIVITIES: 1963 to 2000

by

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- The primary (out of the ground) energy indirectly embodied (not energy content) in imported goods continued to rise during the entire 1963-1980 period; 3.7 percent of Domestic and Imported total energy in 1963 to 10.7 percent in 1980. The energy trade imbalance (inported total energy less exported total energy) grew consistently from 2.5 Quads in 1963 to 10.9 Quads in 1972, and declined slightly to 10.6 Quads in 1980. These results, plus the need for a consistent accounting measure between energy and economic activity, gave rise to a new definition -- the energy consumed per unit of a nation's economic consumption -- the E/GNC ratio.

SUMMARY

- Conventional measures of the ratio of energy consumed per unit of economic activity are inappropriate. Due to increasing amounts of energy embodied in imports and exports, a consumption-based ratio is more revealing.
- Energy conservation, defined as changes in the emphasis on the activities of Final Consumption, accounted for most of the decrease in the ratio between 1972 and 1980.
- Most of this energy conservation effect has already been achieved, according to one set of economic projections. Further decreases in the ratio must come from improvements in production energy efficiency and/or changes in distribution of consumption of industrial products in each of the Final Demand activities.

The research in this paper was conducted over actual and projected data spanning the period 1963 to 2000. Here is a more detailed summary of the results:

- The primary (out of the ground) energy indirectly embodied (not energy content) in imported goods continued to rise during the entire 1963-1980 period; 3.7 percent of Domestic and Imported total energy in 1963 to 10.7 percent in 1980. The energy trade imbalance (inported total energy less exported total energy) grew consistently from 2.5 Quads in 1963 to 10.9 Quads in 1972, and declined slightly to 10.6 Quads in 1980. These results, plus the need for a consistent accounting measure between energy and economic activity, gave rise to a new definition -- the energy consumed per unit of a nation's economic consumption -- the E/GNC ratio.

SUMMARY

- Conventional measures of the ratio of energy consumed per unit of economic activity are inappropriate. Due to increasing amounts of energy embodied in imports and exports, a new energy/trade-adjusted ratio is more revealing.
- Energy conservation, defined as changes in the end-use on the utilization of final consumption, accounted for most of the decrease in the ratio between 1973 and 1980.
- Most of this energy conservation effect has already been achieved, according to our set of economic growth rates. Further decreases in the ratio must come from improvements in production energy efficiency, and/or changes in distribution of consumption to industrial products by many of the Third World countries.

The research in this paper was extended this year and projections spanning the period 1963 to 1990. Here is a more detailed summary of the results:

- The primary fuel of the primary energy content of imports and non-energy commodities plus energy content of imported goods continued to grow during the entire simulated period: 1.7 percent of domestic and imported total energy in 1963 to 20.3 percent in 1980. The energy trade imbalance (imported total energy less exported total energy) grew considerably from 1.2 quads in 1963 to 10.8 quads in 1973, and declined slightly to 10.6 quads in 1980. These results, plus the need for a consistent accounting scheme between energy and economic activity, gave rise to a new definition -- the energy consumed per unit of a nation's economic consumption -- the E/GNC ratio.

- In the period 1963-67, the primary E/GNC ratio grew by 2.7%. The ratio for electricity and natural gas grew by 10.7%. The reason for the growth in the primary E/GNC ratio was clearly a "Market Basket" change, mainly in the Federal Non-Defense and State and Local Government Activities. In other words, the ratio in the first period changed mainly because the average dollar expended on these two Activities grew in energy content, directly and/or indirectly.
- In the period 1967-1972, the primary E/GNC ratio grew by 3.5%. The ratio for electricity and refined petroleum grew by 25.3% and 9.2%, respectively, while the ratio for coal fell by 16.3%. The main reason for the change in the primary E/GNC ratio was "Technological" change, primarily in the construction, petroleum refining and natural gas industries. That is, these industries required increased energy directly and indirectly, per unit of output during the second period. These increases were the main cause of the rise in the primary E/GNC ratio
- The "Distributional" effect, the change in the distribution of expenditures over the Activities of Final Consumption, herein called the conservation effect, had practically no influence on the E/GNC ratio in the period 1963 to 1972. This effect is the only measurable one after 1972. In 1980, the Distributional effect explained about 42 percent of the drop in the E/GNC ratio contributed by the Distributional effect varied widely from 16 to 70 percent.

* In the period 1963-67, the primary E/GNC ratio grew by 2.7%. The ratio for electricity and natural gas grew by 10.7%. The reason for the growth in the primary E/GNC ratio was chiefly a "market basket" change, mainly in the Federal non-defense and State and Local Government Activities. In other words, the ratio in the first period changed mainly because the average dollar expended on these two activities grew in energy content, directly and/or indirectly.
* In the period 1967-1971, the primary E/GNC ratio grew by 4.2%. The ratio for electricity and refined petroleum grew by 15.3% and 0.3%, respectively, while the ratio for coal fell by 10.7%. The main reason for the change in the primary E/GNC ratio was "technological" change, primarily in the construction, petroleum refining and natural gas industries. That is, these industries required increased energy directly and indirectly, per unit of output during the second period. These increases were the main cause of the rise in the primary E/GNC ratio.
* The "market basket" effect, the change in the distribution of expenditures over the activities of final consumption, herein called the compositional effect, has great relative influence on the E/GNC ratio in the period 1963 to 1971. This effect is the only measurable one after 1971. In 1980, the State-and-Local effect explained about 42 percent of the drop in the E/GNC ratio accounted for by the compositional effect; varied widely (from 17 to 78 percent).

- Economic projections of the Distributional effect on the E/GNC ratio for the years 1990 and 2000 show relatively little drop in the ratio (down only 7% between 1980 and 2000) unlike the effect between 1972 and 1980. Accordingly, major future decreases in the E/GNC must come from Technological and Market Basket changes.

INTRODUCTION

As a part of nearly every policymaking effort regarding energy resources, the future demand for energy is estimated. One approach is to estimate the change in future economic activity and then, with an understanding of the connection between various activities and their energy demand, estimate the future demand for energy.

The projections of economic activity at best include the interaction of supply and demand prices of labor, capital, materials and energy. The result is usually a forecast of the change in aggregate economic activity (GNP) and perhaps forecasts of various activities which make up the GNP. If one understood the connection between the types of energy demanded directly and indirectly for units of each of these more detailed activities, a good estimate of the energy demanded for a given forecasted GNP could be obtained.

Thus the questions become: How do changes in the relative levels of the activities of final demand affect the energy used per unit of aggregate economic activity? How do technological changes, both in industrial production and in consumption, affect the energy used per unit of aggregate economic activity.

In this paper these questions are addressed completely in a historical sense for the U.S. economy in the years 1963, 1967 and 1972, and partially for the years between 1972 and 1980, and to a yet lesser degree for the 1980-2000 period. A new energy/economic ratio is defined and compared with the usual definition.

HISTORICAL APPROACH

Bullard and Hannon [1] evaluated the reasons for total energy use change in the 1963-1967 period. Reardon [2] using some of the ERG data and a similar procedure analyzed the reasons for changes in total energy use between 1947 and 1967. The reasons for change in total energy use should not necessarily relate directly to the reasons for change in the energy/economic ratios, however.

Berndt [3] has examined the reason for change in the energy/economic ratio from 1947 to 1971. By "correcting" the energy values for the nature of its end use, he finds the ratio is essentially constant.

Allen [6] also studied and forecast the change in the ratio but his estimates of the level of economic activity were independent of the price of energy. He concluded that the ratio should decline as energy conservation, appliance saturation and an aging population, all act to reduce the future energy use level. R.F.F. [7] has also presented a study which dealt in part with the potential change in the ratio. By assuming a rate of introduction of energy saving equipment and by developing estimates of long run price elasticities, the R.F.F. concluded that the ratio would decline as the real price of energy increases.

Hudson and Jorgenson [4] have predicted that economic activity is reduced in the long run by rising energy prices. The level of energy use is reduced almost immediately, however, but appears to cease to decline while the economic effect continued past the end of their

study period. It appears that rising energy prices may initially lower the energy/economic ratio but raise it in the long run.

Darmstadter, et al [5] have studied the differences in the historic energy/economic ratio between countries. These authors used the Energy Research Group (ERG) input-output model (for 1967) to determine that the intercountry difference was nearly half accounted for by differences in the composition of the final output of the economies. The remaining portion of the difference was due to differences in transportation distances and in technologies of manufacturing.

None of these studies developed a consistent definition of the energy/economic ratio nor sought to systematically decompose it. This paper deals specifically with a consistently defined ratio, the changes in this ratio and the underlying reasons for the changes, to varying degrees, over the period 1963 to 2000.

DEFINING THE APPROPRIATE ENERGY/EOCNOMIC RATIO

Before calculating the aggregate energy intensities, a definition of the measure of energy and economic activity must be chosen. The standard definition of the energy/GNP ratio is not consistent. For example, note the definition used by the U.S. Energy Information Administration in their Monthly Energy Review. The energy counted is all domestically produced plus directly imported energy less the directly exported energy. But the economic activity is measured by taking the value of all final consumption, including exports but excluding imports (i.e., the GNP). Thus this energy measure contains some imported values but the economic activity measure does not; the reverse is true of

exports. In addition, the usual energy measure does not contain the value of energy used by other countries to make goods (including energy) which are imported to the U.S. The ERG calculation of the energy intensities includes this energy embodied in imported goods; the energy embodied in exported goods is also included in the energy intensities.

An internationally consistent procedure, from an energy accounting point of view, would be to exclude the direct and indirect energy and the dollar cost of exports from the ratio and include the direct and indirect energy and the dollar cost of imports in the numerator and denominator, respectively. This ratio represents the <u>energy consumed</u> (directly and indirectly) per unit of net <u>economic consumption</u>. The result is called the energy/GNC ratio, where GNC stands for "Gross National Consumption." The ratio has an interesting trait. All else being unchanged, an increase in the dollar value of imports over exports reduces the ratio. Conversely, an increase in the total energy content of imports over that in exports raises the ratio. This seems to be appropriate behavior for such a ratio. In times of energy scarcity, a declining ratio is considered appropriate. If a country is a net absorber of economic good without an associated increase in net energy absorption, the ratio declines. If they absorb net energy without an offsetting net absorption of economic good, the ratio rises.

In summary the standard ratio is defined as

$$\frac{E}{GNP} = \frac{\text{Energy Produced Domestically plus Direct Energy Imports less Direct Energy Exports}}{\text{Dollar Value of Net Domestic Production (excludes imports but includes exports)}}$$

while the more consistent definition is

$$\frac{E}{GNC} = \frac{\text{Energy Produced Domestically plus Direct \& Indirect Energy in Imports less Direct \& Indirect Energy in Exports}}{\text{Dollar Value of Net Domestic Production plus Value of Imports less Value of Exports}} .$$

The latter definition is used in the remainder of this paper.

GATHERING THE DATA

At the outset the terms for the various processes to be investigated must be carefully defined. Realize that commodities, the output of industrial and commercial producers, are sold to the various Activities of Final Demand or Final consumption. There are 88 commodities delivered for 11 different types of activities. There are 5 different energy commodities; coal, crude petrol, refined petrol, electricity and natural gas. The flows of these commodities are measured strictly in BTU. The remaining 83 commodity flows are measured in dollars. The 11 Final Demand Activities are defined in Table 1.

The analysis of the direct and indirect energy cost (i.e. the energy intensity) of the Final Demand Activities of a given year requires three sets of data: The direct and indirect energy costs of industrial and commercial output, the distribution of the industrial and commercial output across the categories of Final Demand and the set of inflators to convert the current value of the output into constant dollars. All of the basic data for these three data sets are derived from government data.

The first set, the energy costs or energy intensities, (the direct and indirect energy used throughout the economy per unit of commodity output) are derived by the Energy Research Group (ERG) at the University of Illinois. Basically, the input-output (I/O) modeling process is modified to include the energy transactions in physical units. The resulting combined units matrices (BTU and dollars) are manipulated to produce the coal, crude petrol and natural gas, refined petrol, electricity and natural gas energy intensities for each sector of an 88 commercial and industrial

sector breakdown of the U.S. economy [8, 9, 10].

The complete input-output matrix set is now available for the years 1963, 1967 and 1972. The set is consistently defined, based on the flow of commodities rather than industrial output and is in constant 1972 dollars. The derivation of the commodity energy intensities is given in Reference 10.

By judicious substitution of the physical energy data from more recent times (and projected energy use data) the ERG plans to update (and project) the values of these detailed sets of energy intensities. These intensities are called average energy intensities because they are derived for each of the historic hears. A way to calculate new sets of intensities based on the changes in economic exchange from period to period is now being developed. These "marginal" values could be approximated for each historical I/O year and yield the marginal energy cost of the next unit of each sector's output

The second data set, the distribution of output across Final Demand Activities, is compiled from historic data collected by the Bureau of Economic analysis (BEA) of the U.S. Department of Commerce for the years 1963, 1967 and 1972 [11]. The Bureau of Labor Statistics (BLS) has estimated a Final Demand Matrix for 1980 [12]. Actual Final Demand activity distributions were obtained for the year 1972-1980 from BEA [12], all in 1972 dollars. These data are the dollar consumption of the 88 commodity (industrial and commercial outputs) in each of 12 different Final Demand Activities, for each historical I/O year. Table 1a shows the Final Demand breakdown and their sources. Table 1b shows the detail from which the four Personal Consumption Expenditure Activities were formed.

Table 1a. The Definitions of the Final Demand Activities

Final Demand Activities	Source of Data
PERSONAL CONSUMPTION	
Energy	8, 9, 10, 11
Durable Goods	11
Non-Durable Goods (Less fuel oil, gasoline and motor oil expenditures)	11
Services (Less electricity and natural gas expenditures)	11
CAPITAL FORMATION (New, Private)	
Buildings (Defined as "New Construction")	11
New Equipment (Defined as the Remainder of New Private Capital Formation)	11
NET INVENTORY CHANGE	11
EXPORTS	11
FEDERAL GOVERNMENT	
Federal Government Defense Expenditures	11
Federal Government Other Expenditures	11
STATE AND LOCAL GOVERNMENT EXPENDITURES	11
IMPORTS	11

Table 1b. Definitions of the Personal Consumption Expenditure Activities

ENERGY
- Electricity
- Natural Gas
- Fuel Oil & Coal
- Gasoline & Motor Oil

DURABLES
- Jewelry & Watches
- Furniture
- Home Appliances
- Tableware
- Opthalmic & Orthopedic
- New & Used Cars, Accessories & Parts
- Books, Maps
- Toys, Sporting & Recreational Goods
- Radio & TV, Records & Musical Instruments

NON-DURABLES
- Food
- Tobacco
- Shoes
- Clothing
- Soaps, Perfumes, etc.
- Semi-Durable Household Furnishings
- Paper Products
- Drugs
- Magazines, Newspapers
- Flowers
- Expenditures Abroad by Gov't. Personnel

SERVICES
- Shoe Cleaning & Repair
- Laundry & Cleaning
- Barber & Beauty Shops
- Dwelling Rent
- Water & Sanitary
- Telephone & Telegraph
- Servants
- Medical Care
- Insurance
- Legal & Finance Charge
- Funeral, Personal Business
- Auto Repair, Maintenance, Parking
- Taxi & Mass Transit
- Radio & TV Repair
- Movies
- Opera & Sporting Events
- Education
- Religious Activities
- Foreign Travel in U.S.

Since both of the above data sets are in current dollars, a set of inflators is needed for 1963 and 1967 to inflate these dollars to the 1972 level for comparative purposes. A vector for each year was derived with an element for each of the 88 commodities. Inflators for the manufactured commodities were taken from the work sheets of the BEA, the only available source. The remainder of the inflators were obtained from the BLS and the BEA [14, 15].

CALCULATING THE ENERGY INTENSITIES

The next step of the analysis is to determine the total energy used (by type) for each Final Demand category in each year. This is done by multiplying the Energy Intensity matrix times the Final Demand matrix and summing down the resulting columns. To convert each of these results to a Final Demand Activity energy intensity, we must inflate the dollar values in each of the 1963 and 1967 Final Demand categories to 1972 dollars and sum for the total 1972 dollar equivalent for each category. We also inflate the energy intensities for 1963 and 1967 into BTU per 1972 producer's dollar. Dividing the energy values by their respective dollar levels yields the desired energy intensities (by fuel type), for each Final Demand category, for each year.

In mathematical terms, the desired Final Demand Activity energy intensities $<\varepsilon>$, are:

$$\underline{\underline{\langle \varepsilon \rangle}} = \widehat{\underline{d}\underline{\underline{F}}}^{-1} \underline{\underline{\varepsilon}}\,\underline{\underline{F}} \qquad (1)$$

where $\underline{d}$ is the inflator vector which translates the current value of each of the 88 commodities from 1963 or 1967 to 1972 dollars. $\underline{d}$ is the unit vector in 1972.

$\underline{\underline{F}}$ is the matrix which indicates the amounts of the 88 possible commodities used in each of the 12 Final Demand Activities. The energy inputs in this matrix are measured in BTU.

$\underline{\underline{\varepsilon}}$ is the matrix of industrial energy (direct plus indirect) intensities (6 types) for each of the 88 commodities. The units of the intensities for the energy sectors are in BTU per BTU and BTU per dollar otherwise. See references [8, 9, 10] in detailed definitions.

The symbol $\widehat{\ }^{-1}$ indicates that the vector $\underline{d}\underline{\underline{F}}$ is to be diagonalized into a matrix and then inverted. This is the normalizing step.

The results are presented in Tables 2, 3, and 4, for the years 1963, 1967 and 1972. The primary energy intensities are the sum of the coal and crude petrol and natural gas intensity plus the hydro and nuclear power portion of the electricity intensity (converted at the fossil fuel efficiency) [8,9,10]. These primary intensities, indicating the total energy resource taken from the earth, are useful when a single energy measure is desired. This same sort of data was calculated for the BLS estimated Final Demand matrix for 1980. These results are not compatible with results based on actual 1980 data and therefore the BLS data was not used.

Table 2. Energy Intensities [a] (BTU/1972$) & Associated Data: U.S. Economy, 1963.

	Final Demand Category	Coal	Crude Petrol. & Natural Gas	Refined Petroleum	Electricity	Natural Gas	Primary [b]		Total-Billion 1972$
1	Energy Personal Consumption	78115.	448507.	310024.	31387.	167434.	569935.	*	33.667
2	Durable Personal Consumption	18285.	28308.	13561.	3630.	14212.	50129.	*	67.615
3	Non-Durable Personal Consump.	10555.	28078.	15775.	2795.	11752.	41685.	*	198.829
4	Service Personal Consumption	4406.	15174.	9042.	1660.	6486.	21349.	*	207.171
5	Capital Construction	14595.	29340.	16553.	2718.	13317.	47069.	*	72.912
6	Capital Equipment Purchases	22200.	27458.	12613.	3836.	14785.	53289.	*	43.888
7	Net Inventory Change	24310.	72370.	50236.	4979.	22249.	103376.	*	6.759
8	Exports	50776.	52906.	33270.	4076.	17856.	108723.	*	41.393
9	Federal Defense Purchases	11081.	26747.	17710.	2675.	8896.	40763.	*	79.656
10	Federal Other Purchases	6439.	18804.	11971.	807.	6920.	26711.	*	22.544
11	State & Local Gov't Purchase	8917.	19840.	11753.	2568.	8470.	31239.	*	95.400
12	Imports	16528.	174246.	80020.	3633.	30268.	198742.	*	-35.397
	Total Energy Demand,(Quad) [d]	13.061	36.211	22.644	3.247	14.460	53.093		828.441 Total GNC [c]
	Domestically Produced Energy [b,e], (Quad)	12.49	30.04	19.81	3.118	13.39	46.01		GNP = $834.437
	Direct Imports,(Quad)	(0)	2.38	2.29	0.01	0.41	5.09		$834.437
	BTU/GNC	13230.	41070.	25670.	3715.	16560.	58660.		

STANDARD RATIO: (Domestically Produced energy plus Imported Energy content)/GNP = 63,480 BTU/$

[a] An energy intensity is the direct and indirect energy of the stated type removed from the ground in the U.S. and abroad to produce a unit of the stated final demand category (see References 8, 9, 10).

[b] The primary energy is the sum of the coal and crude petroleum-natural gas energy and the hydro and nuclear power portion of the electrical energy. Hydro and nuclear electricity is counted at the fossil fuel conversion rate.

[c] GNC = Gross National Consumption = GNP + Imports - Exports. In this ratio, the BTU contains imported but not exported total energy.

[d] Total energy demand is the sum of the products of the energy intensities times the associated Final Demand dollars for activities 1-11.

[e] See Reference 10 for the basic data from which these numbers were determined.

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Table 3. Energy Intensities[a] (BTU/1972$) & Associated Data: U.S. Economy, 1967.

Final Demand Category	Coal	Crude Petrol. & Natural Gas	Refined Petroleum	Electricity	Natural Gas	Primary[b]	Total-Billion 1972$
1 Energy Personal Consumption	79869,	432179.	303110.	35265.	165067.	559033.	* 39.648
2 Durable Personal Consumption	14129.	25584.	11130.	3511.	14099.	43215.	* 83.970
3 Non-Durable Personal Consump.	9693.	29218.	14846.	3011.	13575.	42293.	* 228.782
4 Service Personal Consumption	5022.	16844.	9604.	1907.	7873.	23973.	* 248.632
5 Capital Construction	13341.	34030.	20548.	2821.	14771.	51026.	* 73.403
6 Capital Equipment Purchases	19047.	25256.	9860.	3970.	15514.	48088.	* 67.297
7 Net Inventory Change	64726.	93949.	43082.	5839.	44015.	168113.	* 12.066
8 Exports	39260.	54060.	26966.	4019.	20402.	98364.	* 55.808
9 Federal Defense Purchases	10098.	28475.	19015.	2384.	9546.	41568.	* 105.127
10 Federal Other Purchases	13113.	36316.	19749.	3124.	15745.	53277.	* 20.173
11 State & Local Gov't Purchase	9813.	23440.	11314.	3321.	13018.	36587	* 123.100
12 Imports	16482.	152082.	73216.	4187.	33757.	177042.	* -48.790
Total Energy Demand[d] (Quad)	15.598	45.115	26.723	4.347	19.513	65.878	1002.198 Total GNC[c] (+21.0% from 1967)
Domestically Produced Energy[b,e], (Quad)	14.80	37.69	23.17	4.143	17.87	57.27	
Direct Imports, (Quad)	0	2.39	2.94	0.014	0.58	5.92	GNP = $1009.216
BTU/GNC	13380.	42000.	25160	4110.	18330.		
% Change in BTU/GNC from 1963	+ 1.1	+ 2.2	- 1.9	+ 10.7	+ 10.7	+ 2.7	

STANDARD RATIO: (Domestically Produced energy plus Imported energy content)/GNP = 65,010 BTU/$ (+2.4 from 1963)

[a] An energy intensity is the direct and indirect energy of the stated type removed from the ground in the U.S. and abroad to produce a unit of the stated final demand category (see References 8, 9, 10).

[b] The primary energy is the sum of the coal and crude petroleum-natural gas energy and the hydro and nuclear power portion of the electrical energy. Hydro and nuclear electricity is counted at the fossil fuel conversion rate.

[c] GNC = Gross National Consumption = GNP + Imports - Exports. In the BTU/GNC ratio, the BTU contains imported but not exported total energy.

[d] Total energy demand is the sum of the products of the energy intensities times the associated Final Demand dollars for activities 1-11.

[e] See Reference 10 for the basic data from which these numbers were determined.

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Table 4. Energy Intensities[a] (BTU/1972$) & Associated Data: U.S. Economy, 1972.

Final Demand Category	Coal	Crude Petrol. & Natural Gas	Refined Petroleum	Electricity	Natural Gas	Primary[b]		Total-Billion 1972$
1 Energy Personal Consumption	65289.	454641.	316516.	43468.	166247.	576293.	*	49.231
2 Durable Personal Consumption	12664.	29730.	13867.	4456.	15650.	46909.	*	110.673
3 Non-Durable Personal Consump	7965.	31590.	16700.	3831.	14391.	43801.	*	270.408
4 Service Personal Consumption	3868.	16239.	10028.	2108.	6659.	22408.	*	307.760
5 Capital Construction	11891.	41359.	26137.	3593.	16294.	58085.	*	99.087
6 Capital Equipment Purchases	16600.	31091.	13132.	4985.	17888.	52618.	*	85.843
7 Net Inventory Change	77646.	50449.	-3224.	9883.	42067.	136485.	*	10.350
8 Exports	30923.	49691.	27408.	4449.	20479.	86310.	*	72.794
9 Federal Defense Purchases	7399.	32599.	23153.	3110.	10051.	43935.	*	73.513
10 Federal Other Purchases	6522.	21114.	11704.	2656.	9478.	30553.	*	28.613
11 State & Local Gov't Purchase	7860.	27148.	14334.	4014.	13503.	39149.	*	150.693
12 Imports	17859.	195209.	92308.	6047.	41044.	225187.	*	-76.199
Total Energy Demand[d], (Quad)	15.553	57.211	34.595	6.437	23.979	80.275		1186.171 Total GNC[c] (+18.4 from 1967)
Domestically Produced Energy[b,e], (Quad)	14.175	42.33	27.56	5.972	20.85	63.11		GNP = $1182.766
Directly Imported, (Quad)	0.	4.850	5.35	0.04	1.051	11.29		
BTU/GNC	11200.	45180.	27480.	5150.	18960.	62380.		
% Change in BTU/GNC from 1967	- 16.3	+ 7.6	+ 9.2	+ 25.3	+ 3.4	+ 3.5		

STANDARD RATIO: (Domestically Produced energy plus Imported energy content)/GNP = 62,900 BTU/$ (-3.2% from 1967)

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[a] An energy intensity is the direct and indirect energy of the stated type removed from the ground in the U.S. and abroad to produce a unit of the stated final demand cateogry (see References 8, 9, 10).

[b] The primary energy is the sum of the coal and crude petroleum-natural gas energy and the hydro and nuclear power portion of the electrical energy. Hydro and nuclear electricity is counted at the fossil fuel conversion rate.

[c] GNC = Gross National Consumption = GNP + Imports - Exports. In the BTU/GNC ratio, the BTU contains imported but not exported total energy.

[d] Total energy demand is the sum of the products of the energy intensities times the associated Final Demand dollars for activities 1-11.

[e] See Reference 10 for the basic data from which these numbers were determined.

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COMPARISONS WITH OTHER RESULTS

Our initial estimates of the Final Demand category dollar values differ slightly from those given by the Bureau of Labor Statistics [16] in the following three categories: Expenditures on Durable Personal items, New Construction and the 3 Government Sectors. Some of these differences were corrected, others were not. Here is the justification.

First of all there is some disagreement on the individual Final Demand and total GNP dollar amounts between the BLS and BEA (Bureau of Economic Analysis).* The largest of these differences is seen in the 1972 Capital Equipment and Total Capital sector. This difference stands as BEA is believed to be the greater expert in this area.

Next, there is a difference between BEA's detailed list of inflators for the manufacturing sectors and BLS' more aggregated list. This appears to be a source of larger disagreement and we believe that it is the basis for the difference between our result and that of BLS for the dollars spent on consumer durables. Since the ERG used the more detailed and combined BEA-BLS analysis for the I/O model we let this difference remain. When our result is compared to the BLS result the difference is +11% for 1963, +5% for 1967 and -4% for 1972.

The BEA inflator for the New Construction category inputs is modified to agree with the BLS values. Our original inflator was from BEA but their confidence in it is not great. The same was done for the wage inflator on wages of government workers. The BEA inflator was much different but their support for the number was weak. Adopting the BLS wage inflator brought the result into near perfect agreement with BLS in the 3 government categories.

*BEA is the source of the economic portion of ERG's Input-Output data.

In Table 5 are the results of the comparison of ERG results for Final Demand dollars with those of the Bureau of Labor Statistics (BLS) [16].

Table 5. A Comparison of ERG and BLS Results for Final Demand Expenditures.

CATEGORY	FINAL DEMAND EXPENDITURES, BILLION 1972 DOLLARS					
	1963		1967		1972	
	ERG	BLS	ERG	BLS	ERG	BLS
Personal, Energy	33.67		39.65		49.23	
Personal, Durable	67.62	60.7	83.97	79.7	110.67	111.2
Personal, Non-Durable	198.83	223.0	228.78	259.5	270.41	299.3
Personal, Service	207.17	217.6	248.63	264.0	307.76	322.4
TOTAL - Personal	507.29	501.4	601.03	603.2	738.07	733.0
Capital, Construction	72.91	73.4	73.40	77.5	99.09	103.5
Capital, Equipment	43.89	43.3	67.30	63.2	85.84	75.4
Inventory Change	6.76	7.8	12.07	12.0	10.35	9.4
TOTAL - Capital	123.56	124.5	152.77	152.7	195.28	188.3
Exports	41.39	42.2	55.81	54.2	72.79	72.7
Federal, TOTAL	102.2	102.2	125.30	125.3	102.12	102.1
State & Local Government	95.4	95.4	123.10	123.1	150.69	151.0
Imports	-35.40	-35.0	-48.79	-50.7	-76.199	-75.9
GNP	834.44	830.7	1009.22	1007.7	1182.77	1171.1

Note that the BLS breakdown does not include a category called Personal Consumption of Energy. These values come from their "Service and "Non-Durable" categories (see Table 1b). Also, the BLS breakdown does not distinguish between Federal Government activities.

The direct energy used of each fuel type agree exactly with Bureau of Mines (BOM) totals for each year because we force agreement with BOM in our original formulation of the I/O models. The total energy values shown in Tables 2, 3 and 4 exceed the BOM totals, however, because we include surrogate energy costs for the production and delivery of imported goods.

No known efforts have been made to calculate the U.S. energy intensities by other researchers. Consequently, we have no clear idea of the errors in the energy intensities. Sensitivity analysis are currently being performed on the three historic I-O matrices.

CHANGES IN THE ENERGY INTENSITIES

Comparing the total energy demanded by the economy in 1967 (65.9 Quads, Table 3) with an earlier ERG result (66.5 Quads, Ref. 8) a slight decrease is found. The same holds true for 1963. This difference has been traced to a decrease in the total energy cost of refined petroleum in the new models. This decrease is due to a shift of some of the input energy of the réfined petroleum sector to the chemical industry. Accordingly, the refined petroleum energy cost of imports declined, causing the drop in overall energy demand.

For purposes of aggregate comparison, the E/GNC ratios for 1972-1980 were estimated using Wharton and some BLS cata. The results are shown in Appendices A & B. Other than these aggregates

and the Final Demand Activity distribution, no detailed and complete data exist for years other than 1963, 1967 and 1972.

The relative changes in the E/GNP and the E/GNC ratios in the first two periods points out the value of the latter ratio in comparing energy use and economic activity. The E/GNP ratio dropped between 1967 and 1972 while the E/GNC ratio rose. This phenomena occurs because of the relative increase in the imports of refined petroleum products. The E/GNP ratio counts only the energy content of these imports while the E/GNC ratio counts this and an estimate of the extra energy needed to refine these imports. A further contribution to this divergence in the ratios in the 1967-1972 period is caused by the decline in the total energy intensity of exports.

From an examination of Tables 2, 3 and 4, and Appendices A and B for 1972 - 1980 aggregates, several results stand out:

1. The E/GNC ratio rose 2.7 percent and 3.5 percent in the first two periods and dropped 15.3 percent between 1972 and 1980. The overall primary energy intensity (primary BTU/GNP) rose for the first period (1963 to 1967) but dropped in the second period (1967 to 1972) (+2.4%, -3.2%) and dropped 13.4 percent in the 1972-1980 period.
2. The overall electricity intensity increased significantly in the first two periods (+10.7%, +25.3%).
3. The overall coal intensity dropped significantly in the 1967-72 period .
4. The primary energy intensities of Exports dropped significantly in the two earlier periods.

5. The Primary intensities of State and Local Government dropped in the first period (electricity, natural gas intensities rose) and all intensities rose in the second period, despite sizable budget growth in the first two periods.

6. The energy embodied in imports (not the energy content) rose from 3.7 percent to 4.1 percent to 7.3 percent to 10.7 percent of the domestic plus imported (total) energy in 1963, 1967, 1972, and 1980, respectively. Thus a growing fraction of the U.S. energy use was in the form of energy used abroad to make and deliver our imports.

7. The net balance of <u>total</u> energy trade (imported-exported energy) rose from 2.5 Quads in 1963 to 3.0 Quads in 1967, to 10.9 Quads in 1972, and dropped slightly to 10.6 Quads in 1980.

DECOMPOSITION OF THE E/GNC RATIO CHANGE

A change in the energy required per dollar of economic activity can be thought of as arising from three separate sources: a change in industrial production technology (the Technological effect), a change in the composition of industrial inputs to a particular Final Demand Activity per unit of that activity (the "Market Basket" effect), and a change in the spending pattern across the activities of Final Demand (the Distribution effect). Of course, the change in an energy intensity is the result of a combination of these three principle sources of change. The technological and market basket sources of change are, in turn, the net result of a series of more detailed specific changes. These more specific changes might be quite large and offsetting, producing a final energy intensity which is small. Nevertheless, we wish to know if this is the case.

How can the sources chiefly responsible for a change in an energy intensity be determined? What follows is a theoretical approximation for the decomposition of the energy-GNC ratio along the lines described above.

Define the direct and indirect total energy use (of the 6 separate types) per GNP dollar as $\underline{\varepsilon}_A$ where

$$\underline{\varepsilon}_A = \underline{\underline{\varepsilon}} \cdot \underline{\underline{f}} \cdot \underline{w} \qquad (2)$$

in which

$\underline{\underline{f}}$ is the matrix of the consumption of commodity output by each Final Demand Activity, divided, down the column by the sum of the activity dollars. The energy rows of this matrix are BTU per dollar and the remainder of the entries are dollars per dollar. This matrix has 88 commodity rows and 12 activity columns.

$\underline{w}$ is a vector of the fractions of the total dollars, spent on each of the 12 Final Demand Activities.

Equation 1 can be written for a spedific fuel intensity as:

$$\varepsilon_A = \underline{\varepsilon}\,\underline{\underline{f}}\,\underline{w} \tag{3}$$

Next, the change in the energy intensity between any two years can be expressed as

$$\varepsilon_A = \Delta\underline{\varepsilon}\,\underline{\underline{f}}\,\underline{w} \; + \; \underline{\varepsilon}\,\Delta\underline{\underline{f}}\,\underline{w} \; + \; \underline{\varepsilon}\,\underline{\underline{f}}\,\Delta\underline{w} + \text{Error term.} \tag{4}$$

The first of the terms is the change in ε_A due to Technological change; the second term is the ε_A change caused by changes in the "Market Basket" composition; the third term is the ε_A change caused by changes in the Distribution of dollars across the Activities of Final Demand; and finally, the fourth term is the residual or "Error" portion, hopefully small, which is the combination of products of the above three changes.

The decomposition shown in equation (4) can be carried out in two rather than three steps. The $\underline{\varepsilon}$ and $\underline{\underline{f}}$ terms could be combined and compared to $\underline{w}$ or the $\underline{\underline{f}}$ and $\underline{w}$ terms could be combined and compared to $\underline{\varepsilon}$. The breakdown in equation (4) requires data and if these data are as accurate as the more aggregate data, the three part decomposition provides more information than a two part form.

Equation (4) was applied to I/O model data for the periods 1963-1967 and 1967-1972. The results are shown in Table 6. The variation due to the four terms in the equation are shown as a percentage of the total variation in the particular energy intensity in question. Looking at the primary row, we see that in the first period, "Market Basket" shifts were the main reason for the change in the E/GNC ratio. By decomposing this Market Basket change, we find that shifts in the Market

Table 6. The Causes of Shifts in the Energy/GNC Ratio for the Periods 1963 to 1967 and1967 to1972.
(See equation 4)

	Percent of the Total Energy/GNC Ratio Change Due, in 1963-1967, to...				Change in
Energy Type	...Technological Change.	....Market Basket Change	..Distrib. Change.	..Error.	E/GNC Ratio BTU/1972$
Coal	-617	+597	+91	+29	+150
Crude Petrol	-1	+153	-31	-20	+940
Ref. Petrol	-99	+ 82	-43	-40	-508
Electricity	+27	+77	+2	-6	+399
Nat. Gas	+52	+55	-6	0	+1772
Primary	-41	+161	-11	-10	+1600

	Percent of the Total Energy/GNC Ratio Change Due, in 1967-1972, to...				Change in
Energy Type	...Technological Change.	....Market Basket Change	..Distrib. Change.	..Error.	E/GNC Ratio BTU/1972$
Coal	-90	-2	+1	-9	-2181
Crude Petrol	+102	-20	+14	+3	+3176
Ref. Petrol	+105	-22	+10	+7	+2320
Electricity	+56	+37	+7	0	+1040
Nat. Gas	+83	-27	+54	-9	+624
Primary	+100	-23	+26	-4	+2123

Basket makeup of the Federal Non-Defense and State and Local Government were primarily responsible (Table 7). From the data in Table 7 we find that all governmental activities account for 65% of the total Market Basket effect. Accordingly, these shifts were primarily the reason for the change in the overall E/GNC ratio. The next step is to decompose the changes in the commodity inputs to these activities with the hope of finding large single input changes causing the shift. The decomposition process can be carried out indefinitely. However, with each deeper step into the cause for change the reasons become diluted.

Most of the energy intensity changes in the first period seem to be related to the Market Basket shift effect. Both the Distributional effects and the "Error" terms were relatively small and generally of the same size (except for refined petroleum).

n the second period, a different result is noted (Table 6). The dominant term is the Technological one, for all energy types. The commodity flow changes for the primary intensity change were decomposed and it was found that the changes in New Construction (also an Activity), petroleum refining and natural gas utility technologies (in that order) were clearly the responsible elements (Table 7). The combined effects of the two energy commodity changes was about equal to the effect of the change in New Construction. One could, of course, seek the reason for these changes. Why did the latter commodity change in the period 1967-1972? The commodity input changes into New Construction could be decomposed to isolate the critical variables.

Note that in the second period, the "error" terms were uniformly small and that, with the exception of the natural gas commodity, the distributional effect is not important. From the study of these three

Table 7. The Source of Change in the Energy/Gross National Consumption Ratio 1963, 1967, and 1972, BTU/$(1972).

1. TECHNOLOGICAL CHANGE $(\Delta\underline{\underline{\varepsilon}}\,\underline{f}\,\underline{w})$. 10 Most Important Commodities.

1963 to 1967		1967-1972	
Motor Vehicles and Parts	-333	New Construction	+847
Gas Utilities	-290	Refined Petrol. Prod.	+427
Drugs	-217	Gas Utilities	+309
Refined Petrol. Prod.	-216	Food	+270
Electric Utilities	-124	Apparel	+169
Auto Repair	+127	Hotels, Pers. Serv	-80
New Construction	+144	Drugs	-85
Hotels, Pers. Serv.	+255	Medical, Ed. Serv.	-108
Trade, Whsle & Retail	+328	Chemical Prod.	-110
Medical, Ed. Services	+508	Real Estate	-311
TOTAL EFFECT	-648	TOTAL EFFECT	+2129

2. MARKET BASKET CHANGE $(\underline{\varepsilon}\Delta\underline{\underline{f}}\,\underline{w})$. Six Most Important Activities.

1963 to 1967		1967-1972	
Fed. Gov't, Other	+759	Net. Invent. Change	-482
State & Local Gov't.	+712	Fed. Gov't. Other	-467
Net. Invent. Change	+584	Non-Durb. Cons.	-137
Capital, Construction	+241	Capital Equip.	+165
Fed. Defense	+214	Durable Cons.	+179
Durable Pers. Cons.	-245	Service Per. Cons.	+242
TOTAL EFFECT	+2579	TOTAL EFFECT	-481

3. DISTRIBUTIONAL CHANGE $(\underline{\varepsilon}\,\underline{\underline{f}}\Delta\underline{w})$. Six Most Important Activities.

1963 to 1967		1967-1972	
Capital, Construct.	-695	Energy Pers. Cons.	+1086
Energy, Per. Cons.	-614	Capital, Constr.	+525
Non-Durb. Per. Cons.	-489	Durb. Per. Cons.	+411
Fed. Defense	+356	Service, Per. Cons.	+273
Net Inv. Change	+401	Net Inv. Change	-557
Capital Equipment	+755	Fed. Defense	-1758
TOTAL EFFECT	-168	TOTAL EFFECT	+559

years, it is surmised that the results of the decomposition process shown by equation (4) are meaningful (small "error" terms).

The 1972 I/O model is the most recent actual data available. However, the BLS has estimated a complete I/O model for 1980 [12]. The 1972 energy intensities were used in conjunction with this BLS Final Demand matrix, to make an estimate of the Market Basket and Distributional effects. Calculation of the actual Distributional effect in 1980 was also made as a check on the BLS result. Unfortunately, the two results do not compare well (see Table 8 and Appendix A). The BLS 1980 model was made in the period 1977-78 and based on the 1958, 1963 and 1967 I/O models and in part on estimates of the 1973 Final Demand activity levels [12]. Consequently, the BLS results appear to be of limited value for the purposes of this paper and the opportunity to accurately calculate the 1980 Market Basket effect is lost.

The actual Final Demand activity expenditures for the years 1973 to 1980 [13] were obtained. These expenditure data are given in Appendix B. The activity primary energy intensities for 1972 ($<\underline{\varepsilon}>$ in equation (1) and the data in the "Primary" column in Table 4) were multiplied times a vector of the normalized differences in expenditures on the activity between 1972 and the year in question. The activity expenditure vectors were normalized by the GNC for their respective year. This is the Distributional term, $\underline{\underline{\varepsilon}}\,\underline{\underline{f}}\,\Delta\underline{w}$, in equation (4). The results are given in Table 8.

Table 8. Percentage change* of Energy/GNC Ratio, Due to Shifts in the Distribution of Total Spending for Each Final Demand Category For each Year, Compared to the 1972 Level.

CATEGORY	1973	1974	1975	1976	1977	1978	1979	1980
PERSONAL CONSUMPTION								
- Energy	-47	-83	+17	-14	-69	-79	-76	-56
- Durables	+51	-5	+2	+29	+41	+44	+17	+2
- Non-Durables	-51	-11	+10	+1	-18	-28	-11	+2
- Services	-8	+18	+27	+40	+30	+34	+22	+18
CAPITAL FORMATION								
- Construction	+48	-47	-55	-80	-55	-48	-28	-25
- Equipment	+27	+20	-9	-18	+15	+29	+20	+8
- Inventory Change	+163	+9	-104	-36	+6	+14	-11	-37
GOVERNMENT								
- Federal Defense	-70	-26	-15	-48	-57	-62	-31	-14
- Federal Other	-13	+1	+3	+3	+6	+1	-1	+1
- State & Local	+1	+25	+24	+25	+0	-4	-0	+0
TOTAL CHANGE RELATIVE TO 1972 BTU/$GNC; DISTRIBUTIONAL EFFECT.	+429	-1206	-1886	-1002	-1048	-1106	-2187	-4012
TOTAL CHANGE RELATIVE TO 1972 BTU/GNC - ACTUAL, ESTIMATED	-1060	-2290	-2680	-3540	-3980	-6950	-6970	-9520
PERCENTAGE OF ACTUAL DIFFERENCE EXPLAINED BY DISTRIBUTIONAL EFFECT	-48	55	70	28	26	16	31	42

*Percentages in column add to 100 percent of the change for the stated year.

In the columns of this table are the percentages of the total change caused by the change in that particular activity, for each year. For example, in 1980, the total Distributional effect was to lower the E/GNC by 4012 BTU/per GNC dollar. Of this total change, 56 percent came from the Personal Energy Activity, 25 percent came from the Construction activity and 14 percent came from the Federal Defense activity changes. These changes were offset by Distributional effect increases particularly in the Personal Services Activity (18 percent). The Personal Energy, Federal Defense and Construction Activities almost consistently contributed the most to the decline in the ratio from the Distributional change perspective from 1972 to 1980. The Activities of Personal Services, Durables, and the New Equipment activity contributed consistently to a rise in the ratio. Non-Defense Governmental activity changes were not important in explaining the Distributional effect.

The next step was to estimate the total change in the E/GNC ratio for each year from 1973 to 1980. The procedure and results are described in Appendices A and B.

The differences between the estimated total ratio, the ratio calculated from the Distributional effect alone, and the 1972 value of the ratio are calculated from the data in Appendix B and presented in Table 8. From the results in Table 8, the following conclusions can be reached: first, the E/GNC ratio is a sensitive indicator of energy price changes. The ratio changed abruptly when the energy price changed in late 1973 and again in 1979-80. The ratio was steady in the intermediate period; second, the change in the ratio due to changes in the Distribution of Final Demand dollars seemed to lag the changes in the total ratio by one to two years (the greatest explanatory fraction

occurring in 1976 and 1980). From these results, one can conclude that although the Distributional effect changes do occur in such a way as to reduce energy use per dollar of economic activity, one of the two other effects must be acting almost immediately to reduce the E/GNC ratio. The Market Basket effect is the natural candidate since technological change is usually thought of as requiring investor confidence and construction time. One can imagine that such changes might be decreased use of electricity, gasoline or fuel oil; purchases of wooden rather than metal furniture, of used rather than new cars, or of natural rather than synthetic fiber clothing, reduced construction of steel buildings, increased purchase of used rather than new equipment; and finally, decreased government expenditures on highway and reservoir construction relative to the level of government service expenditures. In general, if the degree of spending on a particular Final Demand Activity shifts from energy intensive to non-energy intensive commodities, the energy/GNC ratio declines.

Estimates of the Distributional effect on the E/GNC ratio* were also made for the years 1980, 1990 and 2000 and given in the last 3 columns of Appendix B. The DRI estimate for 1980 (all forecasts were made in September of 1980) produced a ratio close to the more correct value for 1980 (compare 58454 with 58367). The values for 1990 and 2000 decline only 3 to 4 percent per decade while the actual 1980 value of the E/GNC ratio (distributional effect only) had declined 14.5 percent between 1972 and 1980 and 3% between 1979 and 1980 alone. From this we can tentatively conclude that the Distributional effect (effect of energy conservation) had nearly run its course by 1980. Thus, providing

*Conservation effect, as defined in this paper.

energy prices are close to those in the DRI forecast, any substantial changes in the E/GNC ratio can be expected to be produced by technological change and changes in the Market Basket of each of the Final Demand Activities.

NEEDED RESEARCH

Future concentration should be on forecasting technological production changes and changes in the mix of commodities produced for Final Demand. These are difficult tasks and do not yield well to standard forms of economic analysis. Forecasting technological change is usually the domain of the engineer. Market Basket change forecasts are in the purview of business analysists, especially if the change is not price but behaviorally induced. Personal consumption is probably done with more price consciousness than Government Consumption for example. Perhaps what is needed is a team comprised of engineers, economists and market analysts, to forecast technological change (in industry and commerce), price-induced change in personal consumption and capital formation and behaviorally induced changes in Government, Exports and Imports, respectively.

In the context of energy conservation, these conclusions have interesting implications. Total energy-saving technological changes occurring in industry and commerce can be defined as <u>energy efficiency improvements</u>. Market Basket and Distributional shifts which save total energy, whether induced by price or behavior, can be defined as <u>energy conservation actions</u>. Which of these two pheonomenon is the most likely to produce significant fuel use shifts and reductions?

Although a great deal of useful information has been gained about the change in the flow of energy through the historic U.S. economy, more recent data are needed. As a result of the research thus far, several important directions need to be pursued. Generally this research is directed toward quantitatively improving our understanding of the three sources of change in the E/GNC ratio: Technological, Market Basket, and Final Demand Distribution.

1. Updating the Input-Output information will improve our grasp of Technical change. It will soon be possible to obtain detailed direct energy flow for 1975, 1976, and 1977 in a form adaptable to the present set of I/O models. It may be possible to combine these direct energy data bases with the 1972 non-energy I/O flows to produce a satisfactory result. Sensitivity analysis needs to be done on the present model set to determine the optimum procedure for such substitution. Depending on the results of such analysis, projected energy use data may be sufficient to develop a reasonably accurate view of future energy flows through the economy. In any event with a 1963, 1967, 1972, and 1977 detailed set of I/O energy models, the first comprehensive yet detailed view of the real reaction of the economy could be studied to observe the actual effects of new technology, changing market basket, changing Final Demand Activities and rising real energy prices. The direct and indirect energy intensity of every U.S. commodity can be historically determined. Consequently, one can rank these commodities to determine the most energy intensive and most total energy using sectors. If important energy

saving technology were to appear in these sectors the impact on the E/GNC ratio would be significant. The latest (and proposed) technological change can be modeled in the context of the whole economy and effects on the E/GNC ratio could be estimated.

2. A very promising line of inquiry would be the examination of the Market Basket effect alone. Data on the industrial composition of Final Demand is available for every year from prior to 1963 up to 1980. A comparison of the effect of these changes on the energy/GNC ratio may be most instructive. For example, the growth of the industrial service sector relative to manufacturing has been substantial in recent years [17]. How do such changes affect the Energy/GNC ratio? Can such shifts continue in the face of rising real energy prices? What shifts might actually be expected to be caused by rising energy prices?

3. It is possible that some of the activities of Final Demand are causing one type of shift in the energy/GNC ratio while other activities cause an opposite form of shift. For example, the Personal Consumption Expenditure Market Basket should shift dramatically during times of rising real energy prices, because consumers seem to be price sensitive. So the Energy/GNC ratio would be affected by the Market Basket change of Personal Consumption. At the same time the Government expenditure market basket should not vary much due to energy prices as these activities are policy driven. Government activities might well affect the ratio by changes in distribution of dollars among their activities (e.g., a shift from Health programs to Defense spending). The data from 1963 to 1977 should be examined with a mechanism more refined than equation (4), to

allow the selective combination of various Final Demand activities. For example, one may wish to explore the combined effect of changes in the Personal Consumption Market Basket with changes in the Distributional effect among the Government activities.

With the results of these three steps an increasingly accurate and prompt estimate of the connection between economic activity and subsequent energy demand could be maintained and forecasted.

APPENDIX A

CALCULATION OF THE ENERGY/GNC RATIOS FOR 1973-80, COMPARISON OF THE DISTRIBUTIONAL EFFECT ON THE RATIO, AND A COMPARISON TO THE ESTIMATED RATIO DERIVED FROM BLS DATA.

To calculate the E/GNC ratio for a given year, the U.S. production of energy and the total (direct and indirect) energy embodied in imports and exports must be known. For the years 1973-1980, the net energy in the latter category is determined by multiplying the energy directly imported less the energy directly exported (by type of energy) [18] with the 1972 fuel energy intensities [10] and adding:

i) for the years 1973-1979; the dollar value of the non-energy imports times the special import energy intensity prepared from the 1972 energy intensities and the 1972 distribution of non-energy imports. The same is done for non-energy exports. The dollar value of imports and exports (energy and non-energy) were obtained from Wharton [20], the only reference obtainable. The distribution of these components of the imports and exports vectors in each year were calculated and shown to be relatively steady over the period. Therefore, the aggregation of these vectors for use with a single 1972 energy intensity is sufficiently accurate for our purposes.

ii) for 1980; detailed Wharton data on imports and exports did not exist so BLS estimated data for the non-energy portion of the net import (imports less exports) vector was multiplied by the corresponding 1972 energy intensities [10].

iii) for the years 1973-1980; the energy produced in the U.S. [18].

The resulting energy values are divided by the GNC values from the corresponding year. These data and results are given in Appendix B.

In 1972 the E/GNC ratio was 62379 BTU/$(1972) and the difference from 1972 to 1980 is -9520 BTU/$(1972). By calculating the Distributional effect for 1972 - 1980 (the third term in equation (4)) using actual 1980 data it is found that this change accounted for -4012 BTU/$(1972) (see Table 8) or 42 percent of the total 9520 BTU/$ drop. Using instead the BLS estimated 1980 Final Demand Distribution, the Distributional effect is -716 BTU/$ or only about 12 percent of the total. The Market Basket change effect between 1972 and 1980 was calculated using the BLS Final Demand estimates and this effect would have raised the Energy/GNC ratio by 981 BTU/$. This is an unlikely result as the period was noted for rising real energy prices. Thus the BLS projection is very suspect and was not considered further.

The BLS is the only source of data for 1980 which details the use of commodities in Final Demand Activities. Their task of estimating the details in a rapidly changing economy is extremely difficult, even with a short projection time.

The estimated import of embodied energy for 1980 is 10.7 percent of the sum of domestically produced plus directly imported energy, up from 7.9 percent in 1972. The estimated balance of energy trade (total imported less total exported energy) was 10.6 Quads in 1980, down slightly from 10.9 Quads in 1972.

APPENDIX B

THE ECONOMIC ACTIVITY LEVELS FOR FINAL DEMAND ACTIVITIES 1973 to 1980 - BILLIONS OF 1972 DOLLARS [13]

	1973	1974	1975	1976	1977	1978	1979	1980	BLS PROJECTED 1980 [12]	DRI PROJECTED [19]		
										1980	1990	2000
PERSONAL CONSUMPTION:												
Energy	51.008	48.509	50.416	52.617	54.324	56.467	55.846	53.682	60.535	51.124	58.047	64.468
Durables	121.322	112.348	112.668	126.548	138.396	146.332	146.627	135.827	160.354	133.042	202.726	277.744
Nondurables, excluding fuel oil, gas, and motor oil	276.389	274.295	278.431	291.067	30.1816	312.043	321.817	327.915	332.585	319.587	390.151	470.028
Services, less electricity and natural gas	319.720	328.355	338.688	353.444	369.350	389.978	406.543	417.673	413.054	412.629	552.347	691.116
CAPITAL FORMATION:												
Building	107.950	90.043	78.835	88.944	99.355	105.059	105.590	94.561	104.018	90.883	128.131	131.381
New Equipment	92.416	93.810	82.674	87.800	101.844	110.728	116.866	111.994	111.371	97.334	143.723	203.779
NET INVENTORY CHANGE	17.175	11.600	-6.725	7,750	12.350	13.950	10.175	-2.950	17.64	-3.272	11.874	12.587
EXPORTS	97.275	108.500	103.550	110.100	113.175	127.525	146.925	161.075	117.003	128.276	188.375	277.382
FEDERAL GOVERNMENT:												
Defense	68.350	66.900	66.425	64.950	65.400	65.375	67.100	70.900	73.934	69.218	105.296	128.226
Other	27.575	29.700	31.00	31.850	35.300	34.375	34.625	37.175	31.292	37.900	39.518	44.525
STATE & LOCAL GOVERNMENT EXPENDITURES	157.500	164.500	166.250	170.025	171.625	178.000	180.125	181.850	190.53	173.817	211.119	253.214
IMPORTS	81.750	80.675	71.375	84.675	91.250	102.950	109.175	109.100	101.13	100.835	140.131	202.192
GNP	1254.98	1247.885	1230.837	1300.420	1371.685	1436.882	1483.064	1480.602	1511.217	1409.703	1891.176	2352.258
GNC	1239.455	1220.060	1198.662	1274.995	1349.76	1412.307	1445.314	1428.627	1495.327	1382.262	1842.932	2277.068
E/GNC* BTU/$	62808	61173	60493	61377	61331	61273	60192	58367	61663	58454	55972	54120
E/GNC Est. Actual	61320	60090	59700	58840	58400	55430	55410	56157	56157	53919	-	-

*Distributional effect only:: Relative to 1972 technology and market basket; See Equation 4.

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